Diffractive Results at CDF II

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ISMD 2003, Krakow, Poland

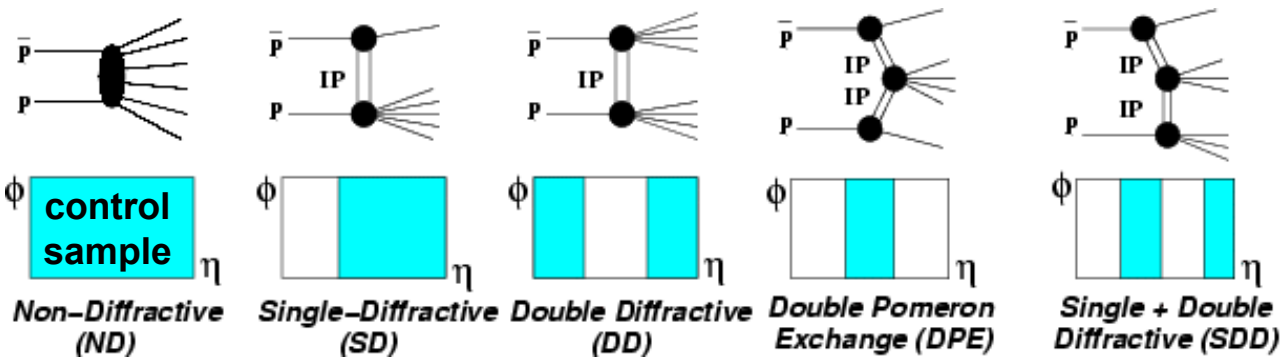
- ✓ **Diffraction at the Tevatron**
- ✓ **New Detectors for Run II**
- ✓ **Diffractive Dijets**
- ✓ **DPE Dijet Production**
  - **exclusive dijet production**
  - **exclusive low-mass states**

Diffraction at the Tevatron

➢ **Large rapidity gaps are signatures for diffraction**

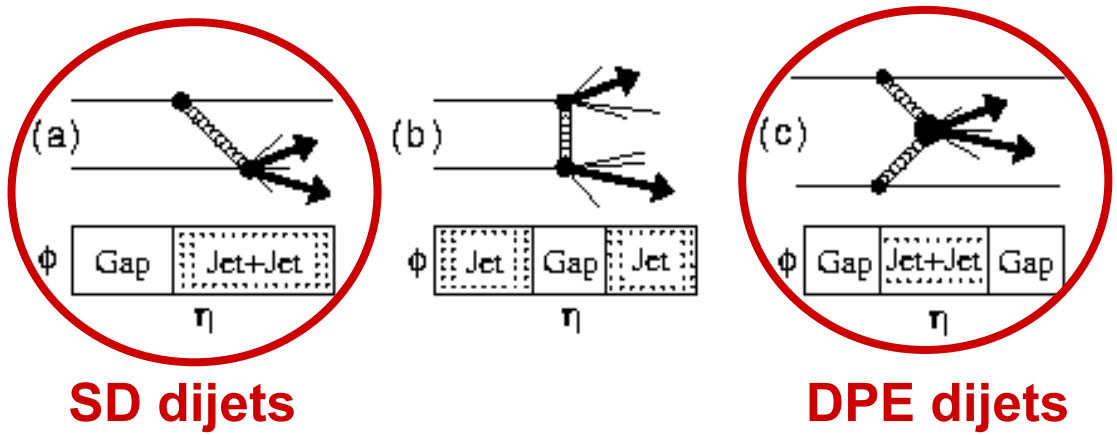
Soft diffraction

- ✓SD
- ✓DD
- ✓DPE
- ✓multi-Gap



Hard diffraction

- ✓SD (W, jet-jet, b-quark, J/ψ)
- ✓SD (w/RP) dijets (630 GeV and 1.8 TeV)
- ✓Forward jets (Jet-Gap-Jet)
- ✓DPE dijets



SD dijets **DPE dijets**

If you want to know more…

Soft diffraction	SD	PRD 50 (1994) 5535
	DD	PRL 87 (2001) 141802
	DPE	to be submitted to PRL
	multi-gap	to be published in PRL
Hard diffraction	W	PRL 78 (1997) 2698
	b-quark	PRL 84 (2000) 232
	J/ψ	PRL 87 (2001) 241802
	jet-jet	PRL 79 (1997) 2636
	jj w/RP	PRL 84 (2000) 5043, PRL 88 (2002) 151802
	forward jets	PRLs 74 (1995) 855; 80 (1998) 1156; 81 (1998) 5278
	DPE dijets	PRL 85 (2000) 4217

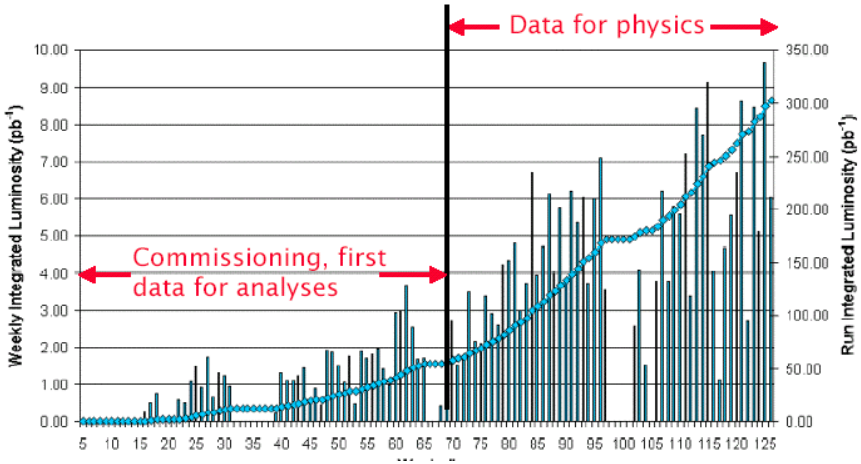
for a review: K. Goulianos hep-ph/0306085

First Goals for Run II

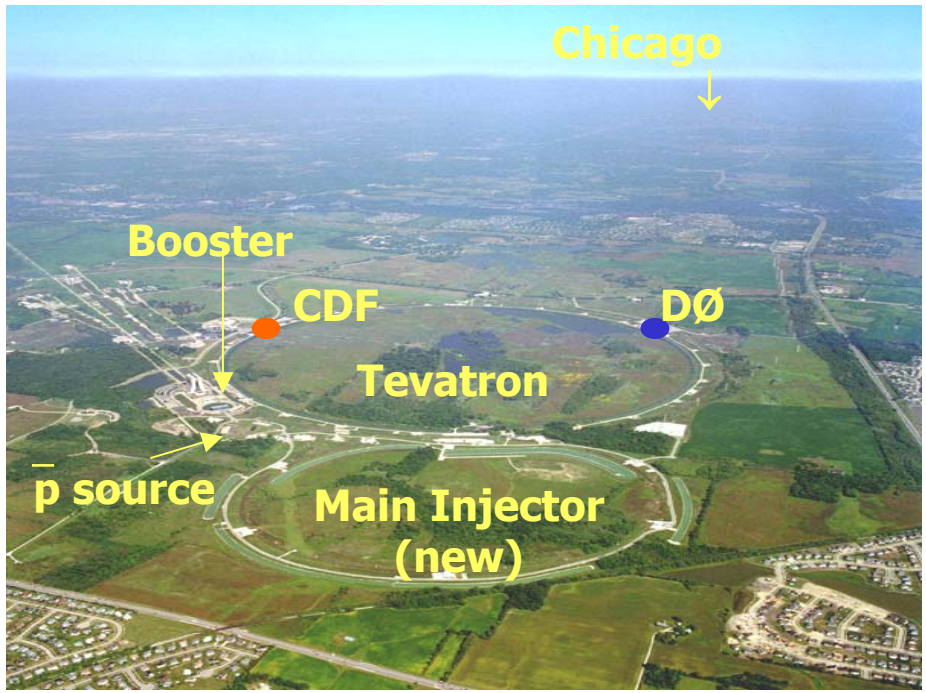
✓Diffractive structure function
⇨ Q^2 and ξ dependence

✓Exclusive production
⇨ dijet, heavy flavor, low-mass

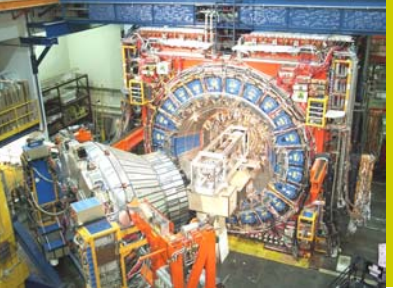
Tevatron Collider



- Tevatron and detector upgrades
  - ✓C.M. energy 1.96 TeV
  - ✓ 396 nsec bunch spacing

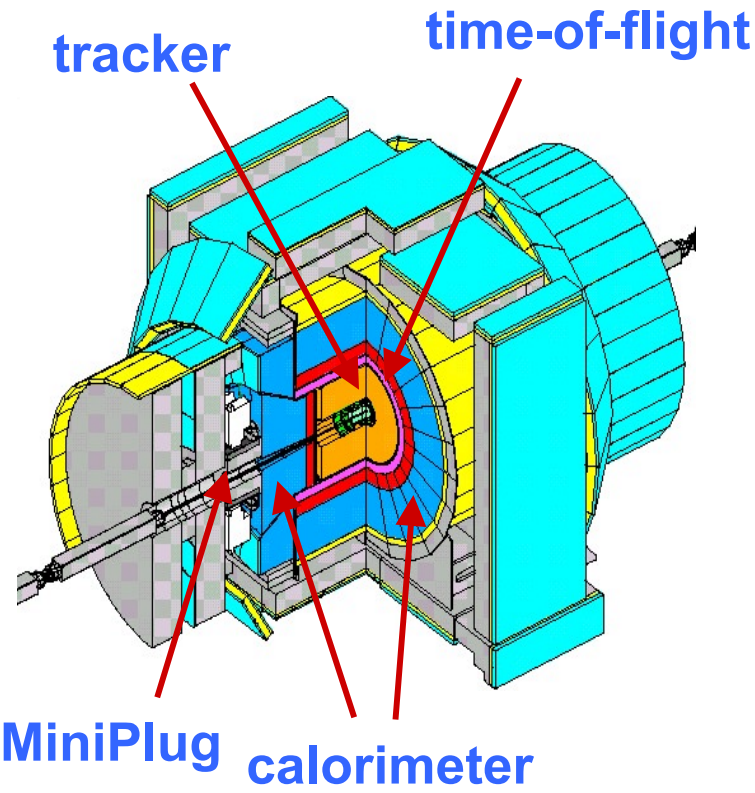


- high (low ?) inst. luminosity
  ($L \sim 2\text{-}3 \times 10^{31}\ cm^{-2}sec^{-1}$)
- multiple interactions

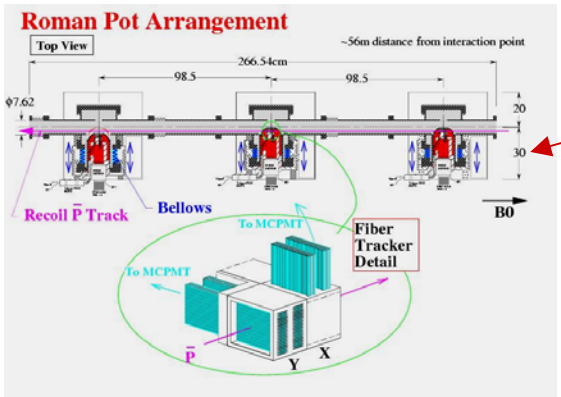


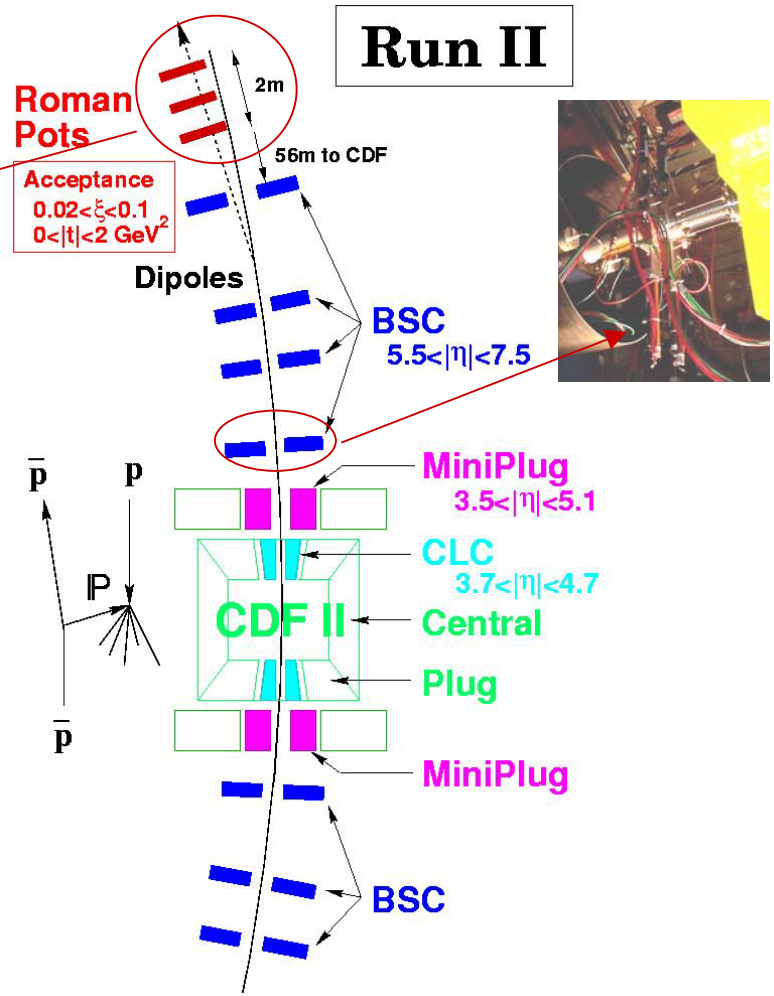
New Detectors for Run II

- Tracking
  - ✓ Silicon
  - ✓ Central Outer Tracker
- Time of Flight
- Expanded Muon Coverage
- Endplug Calorimeter
- **Forward Detectors**
- Trigger
  - ✓ Tracks @ L1
  - ✓ Silicon Tracks @ L2
- DAQ (132 ns)



Forward Detectors



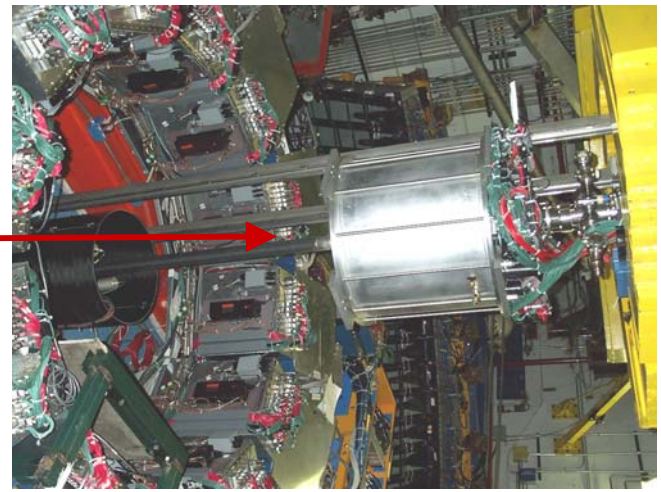


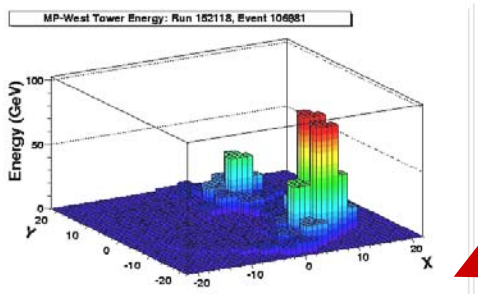
- ✓Roman Pots Spectrometer
- ✓Beam Shower Counters
- ✓MiniPlug Calorimeter

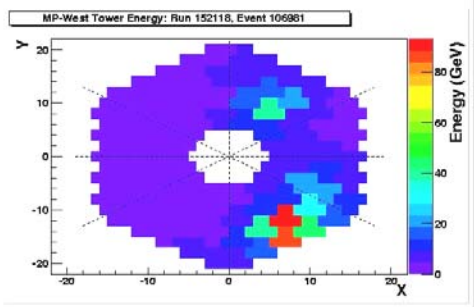
⇨ Larger η coverage for rapidity gaps and jets

New MiniPlug Calorimeter

- liquid scintillator + lead
- towerless geometry
- full coverage: $3.5 < |\eta| < 5.1$
- 32 r.l.
- installed in November 2001



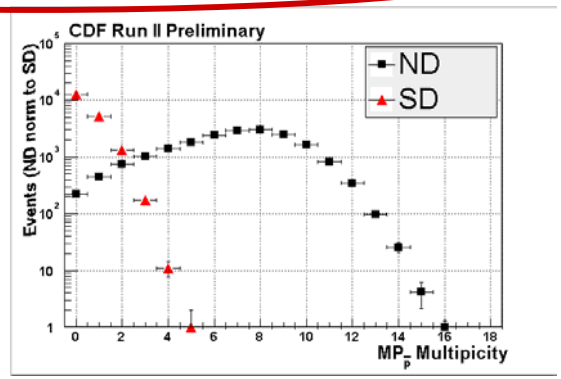




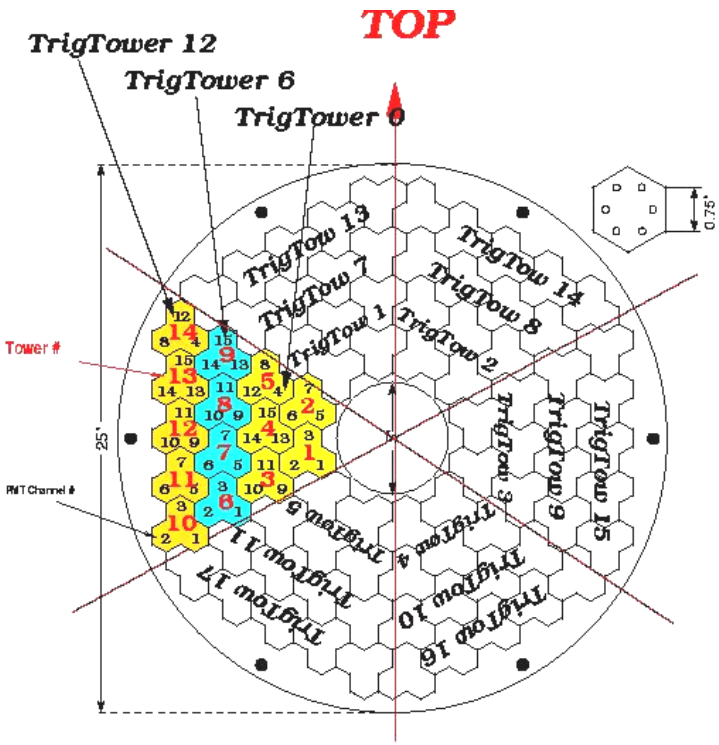
Measure:

very forward jet energies and position

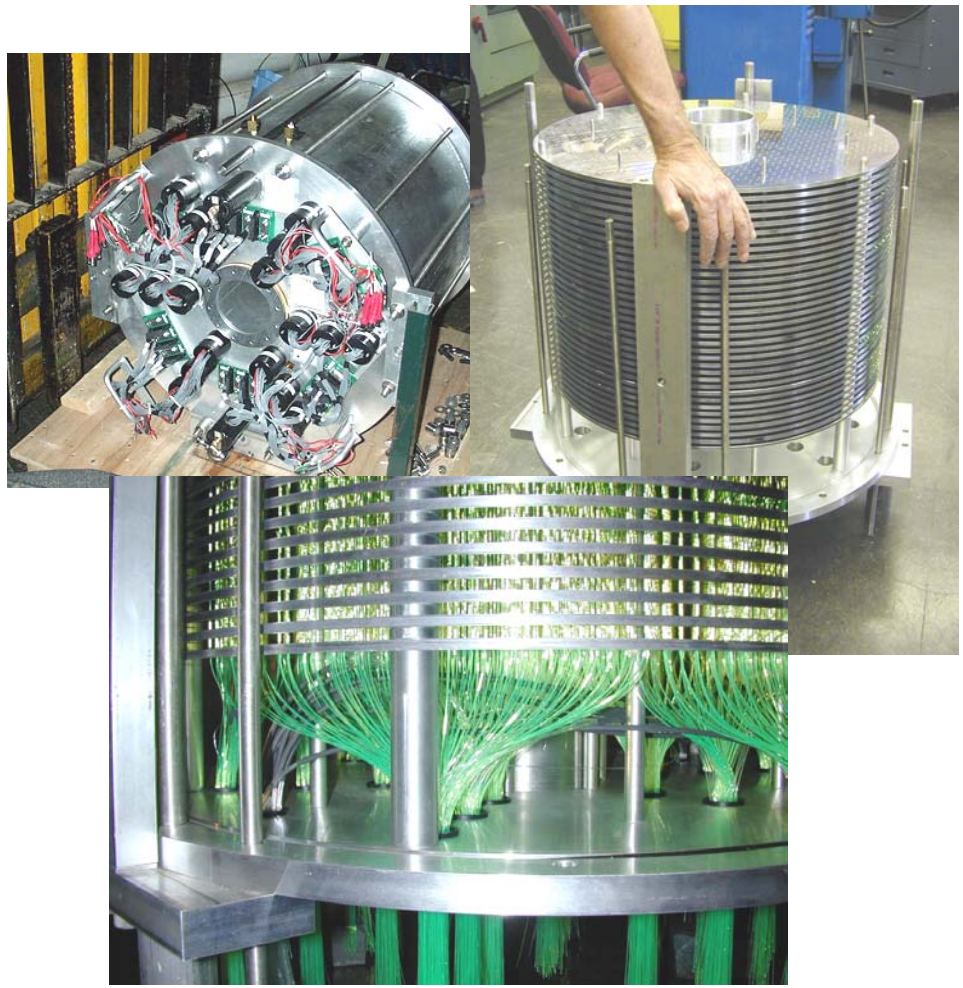
multiplicity



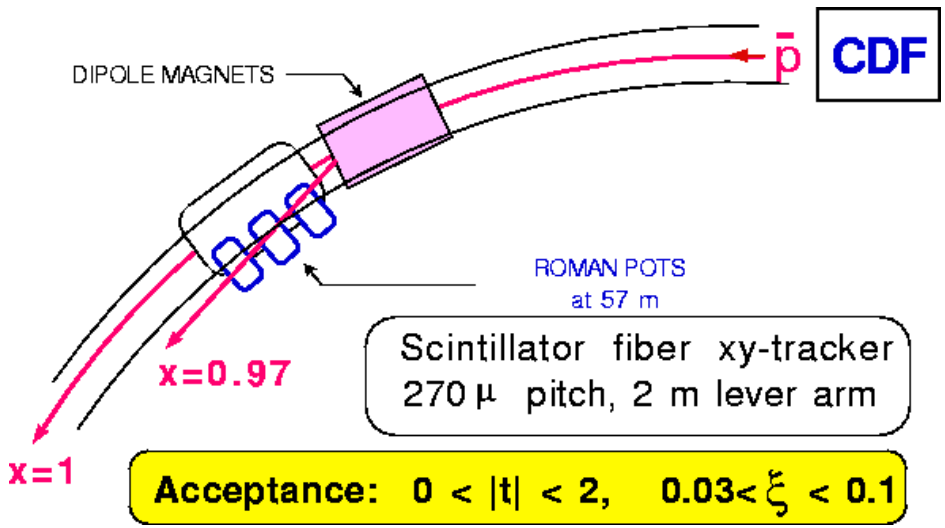
MiniPlug Design



East MP (viewed from IP)



Trigger

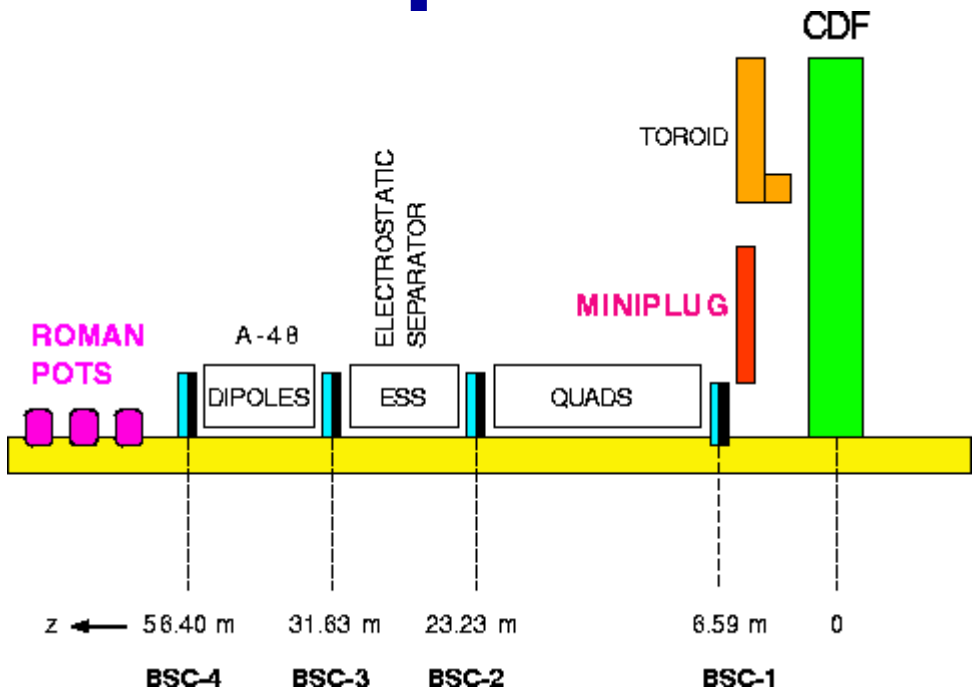


require jets

- RP is triggered on leading antiprotons
- Use RP + jet triggers

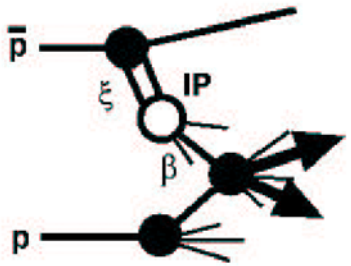
Event Samples

Dedicated triggers
⇨ total rate ~3Hz



ND (J5)	at least one calorimeter tower with E_T>5 GeV
RP inclusive	three-fold coincidence in RP counters
RP+J5	RP inclusive together with J5
RP+J5+BSC_Gap_P	DPE dijet candidates

Diffractive Dijets



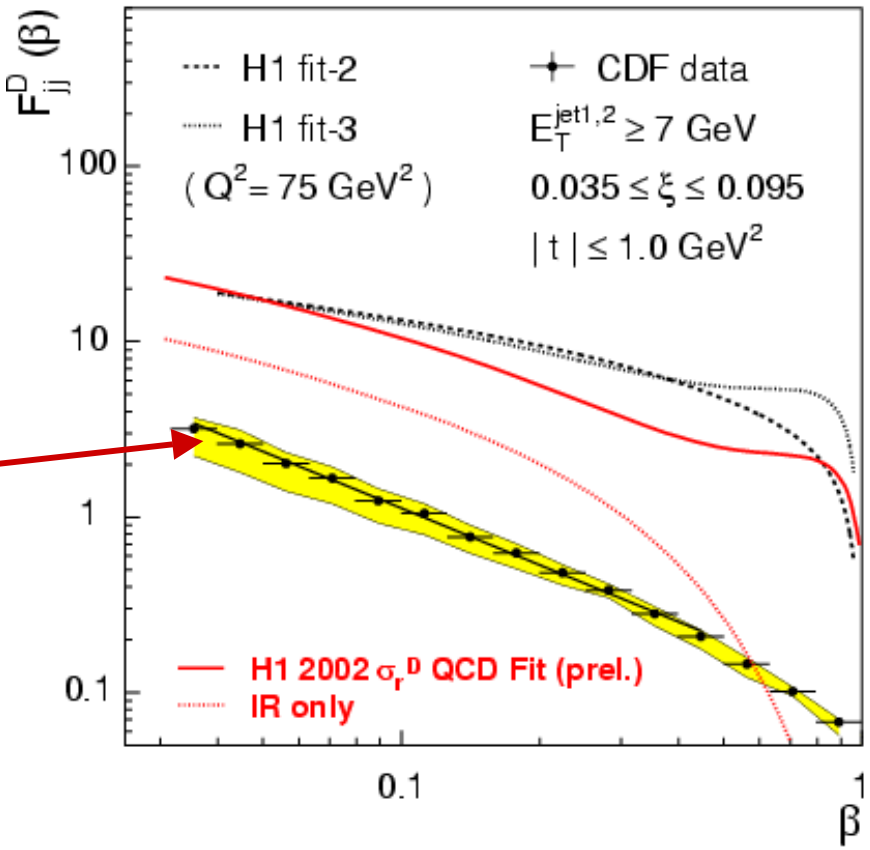
ξ: fraction of anti-proton momentum loss
β: fraction of pomeron momentum carried by parton

parton $x_{Bj} \equiv \beta \cdot \xi$

$$\frac{\sigma(SD_{jj})}{\sigma(ND_{jj})} = \frac{F_{jj}^{D}(x)}{F_{jj}(x)}$$ (LO QCD)

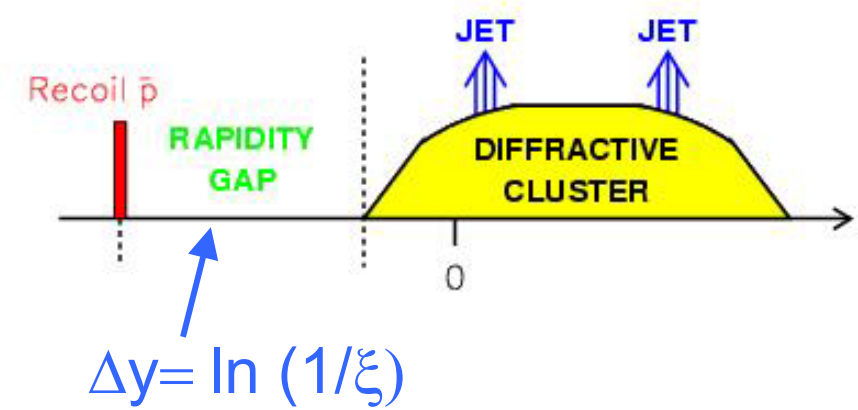
CDF Run I result suppressed
by a factor of ~10 relative to HERA

⇨breakdown of QCD factorization
(renormalization removes s-dependence)
K. Goulianos, PLB 358 (1995) 379



ξ : Momentum Loss Fraction

Measure fractional momentum loss of anti-proton



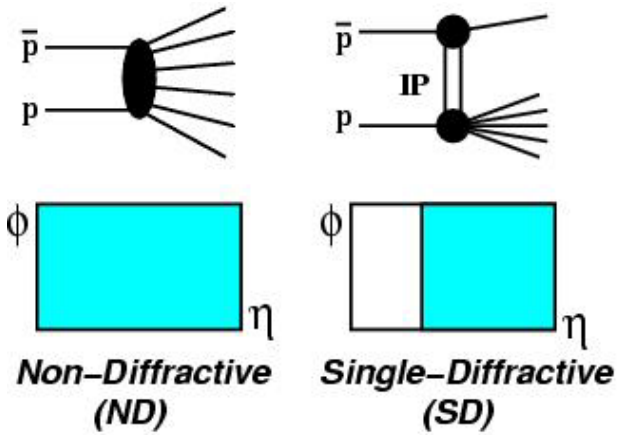
$$\xi = \frac{M_X^{\,2}}{s}$$

$$\Rightarrow \quad \xi = \frac{\Sigma\, E_T\, e^{-\eta}}{\sqrt{s}}$$

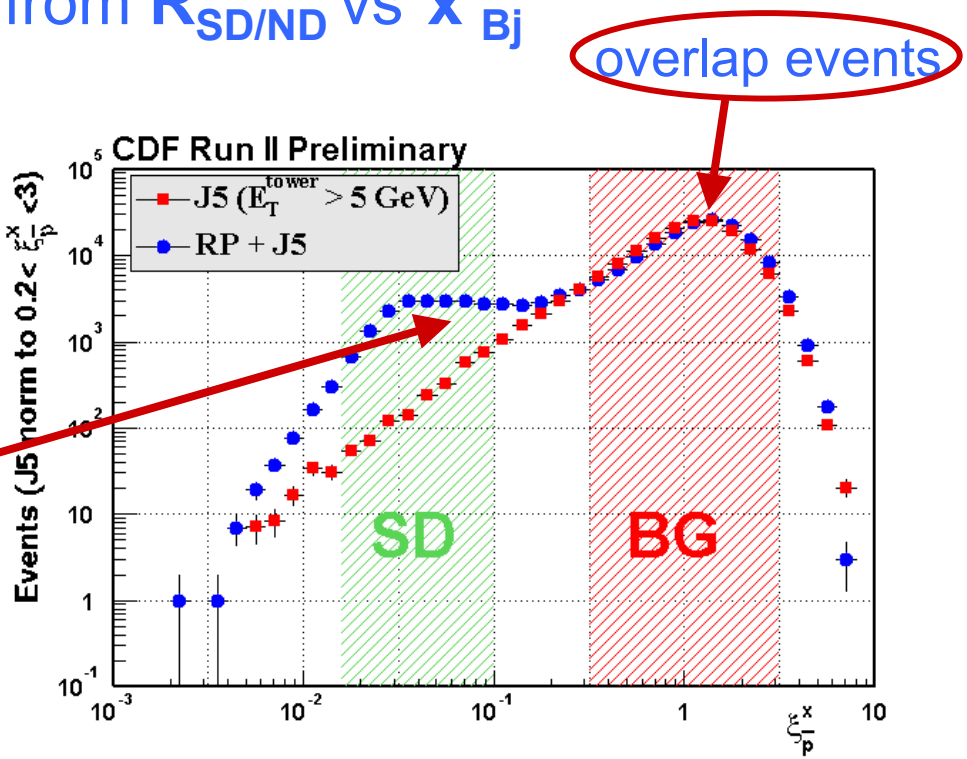
Diffractive events are boosted towards positive η

$\Rightarrow$ small ξ

Single Diffractive Dijets



- Compare diffractive events to ND
- Measure diffractive structure function from $R_{SD/ND}$ vs x_{Bj}



Measure ξ ($\bar{p}$ momentum loss fraction) from calorimeter information

Approx. flat at ξ<0.1

$$\frac{d\sigma}{d\xi} \propto \frac{1}{\xi} \rightarrow \frac{d\sigma}{d(\log \xi)} = \text{constant}$$

SD: Event Selection

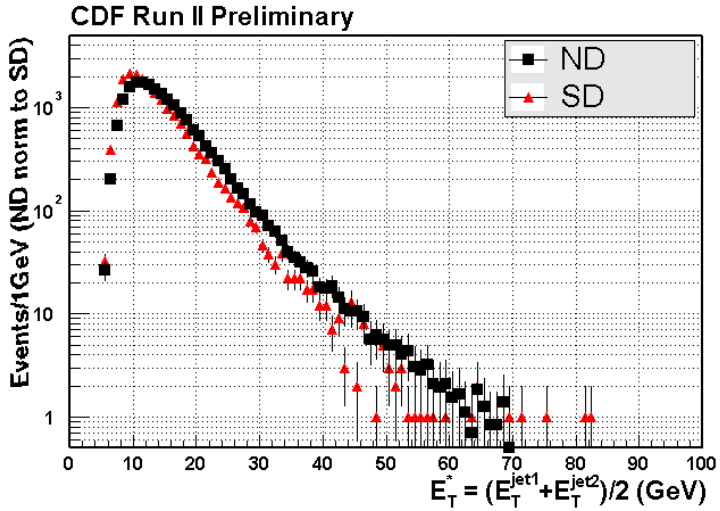
Data presented from 8 pb^{-1}:

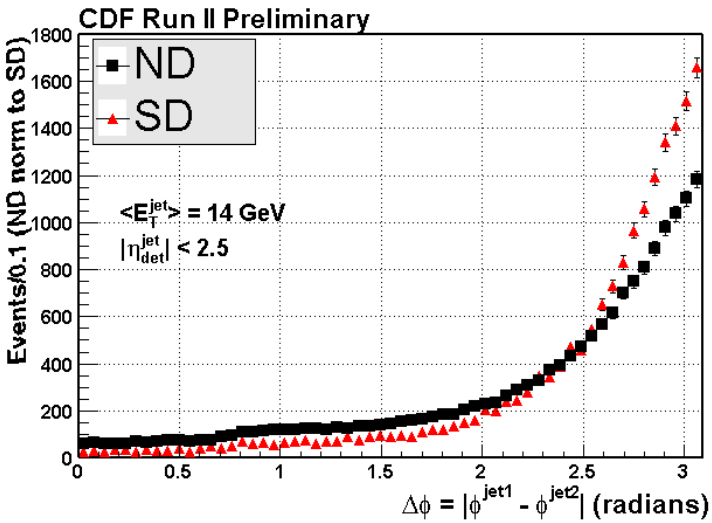
RP+J5	352,359 events
$\geq$ 2 Jets (E_T>5 GeV, $\|\eta\|$<2.5)	175,292 events
RP offline coincidence	168,153 events
SD (0.02<ξ<0.1)	15,209 events

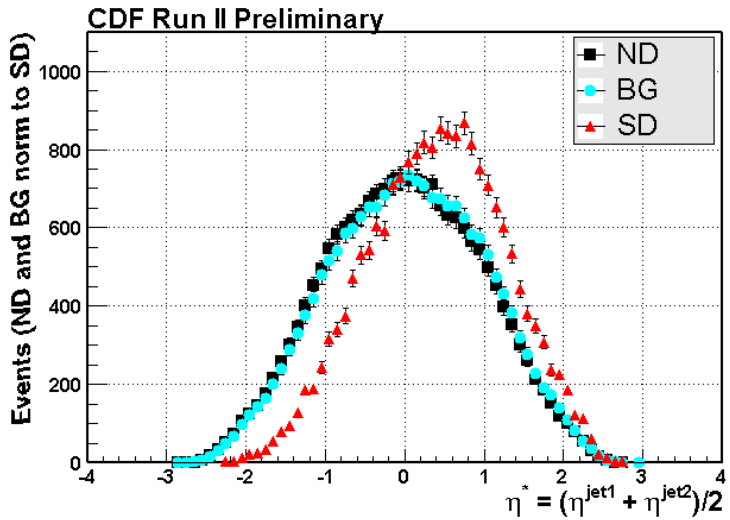
- ✓**RP acceptance ~80% (from Run I)**
- ✓**negligible (< 1-2%) RP background trigger**

Kinematic Properties

Compare ND and SD





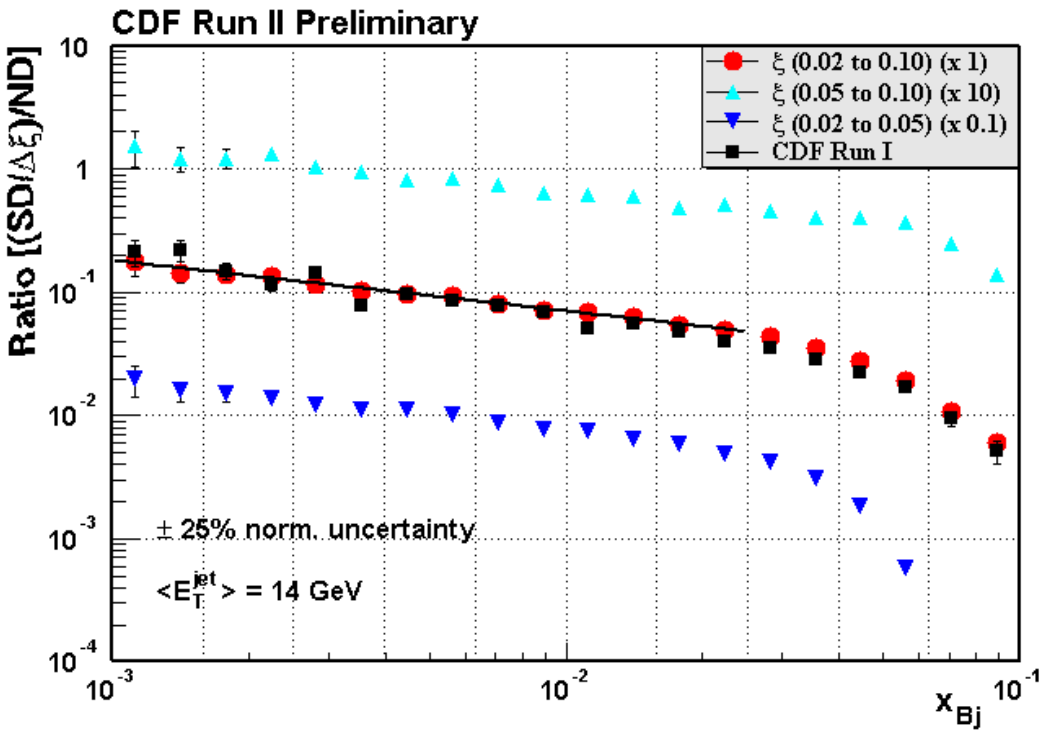


Ratio of SD/ND Events

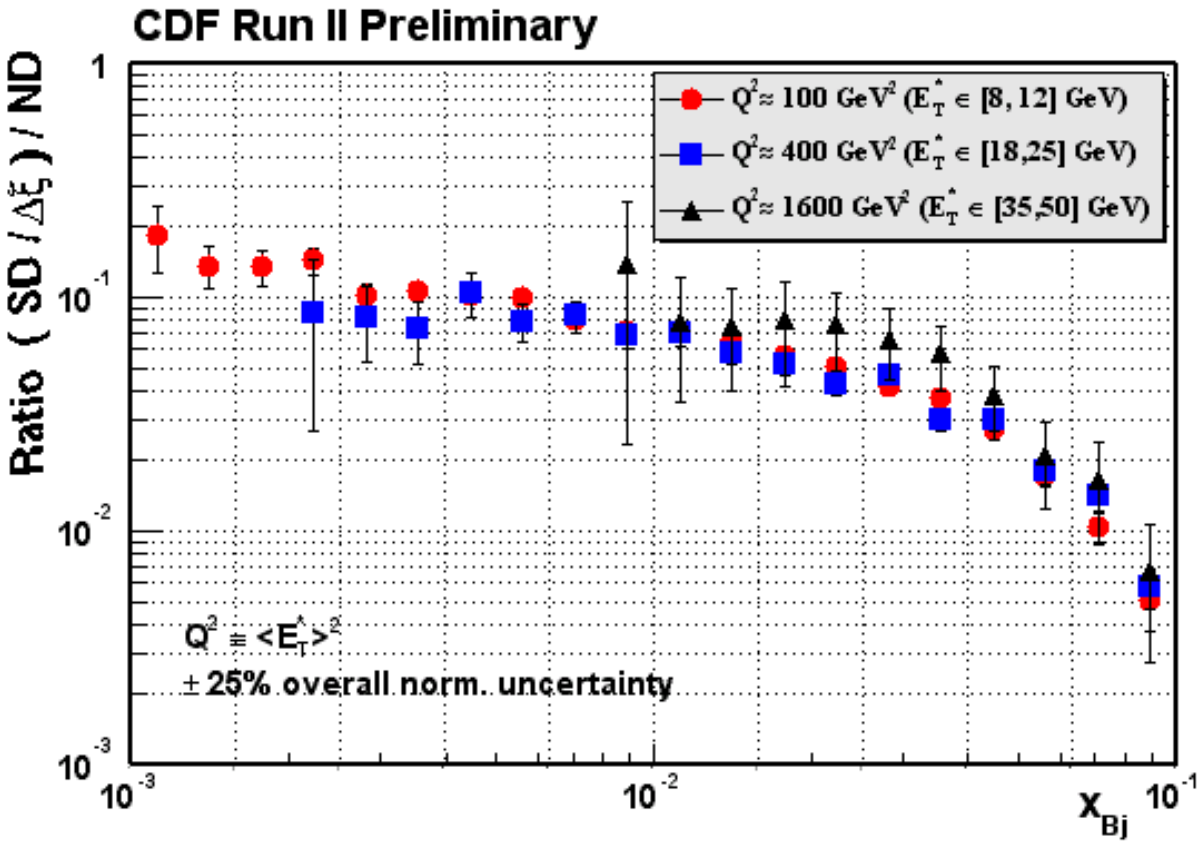
$$x_{Bj} = \frac{\Sigma_{jet} E_T e^{-\eta}}{\sqrt{s}}$$

(jet=1,2,3 if E_T>5 GeV)

- slope and normalization agree with Run I result
- no appreciable ξ dependence (as in Run I)
- work in progress to evaluate ratio at smaller ξ values



Q^2 Dependence



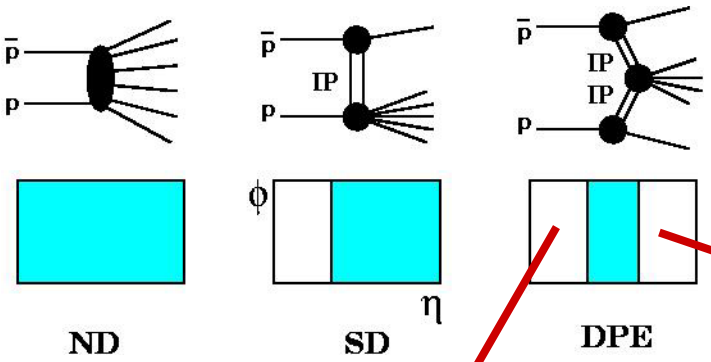
$$E_T^* = \frac{E_T^1 + E_T^2}{2}$$

- mean dijet energy intervals
- overall norm. only

⇨ ratio is independent of Q^2
Pomeron evolves similarly to proton (?)

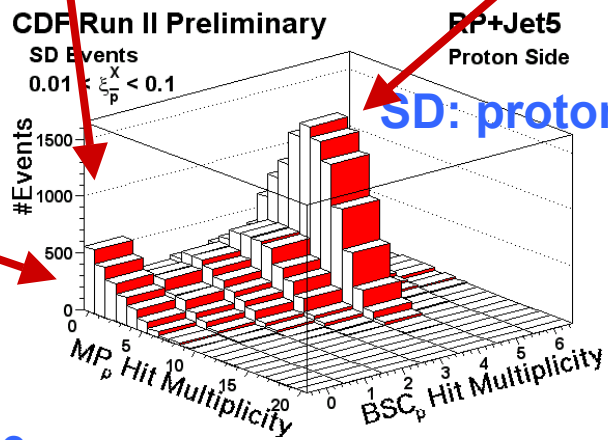
DPE Dijet Production

from SD data:

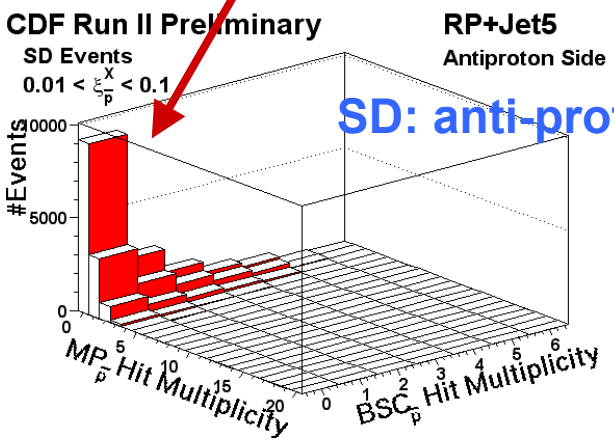


DPE

SD

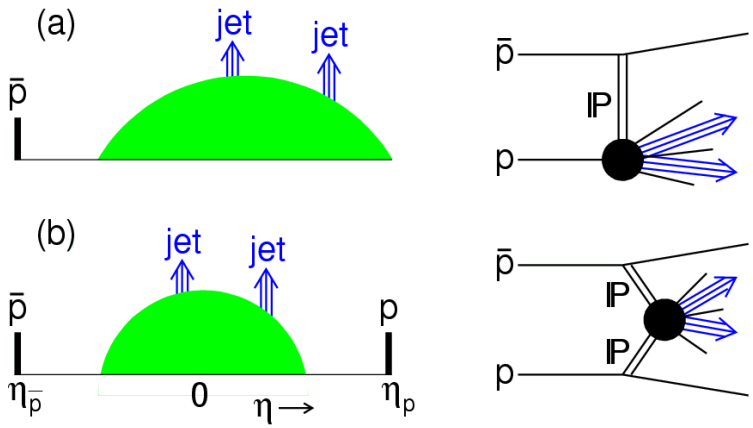


SD: proton side



SD: anti-proton side

DPE Dijets in Run I



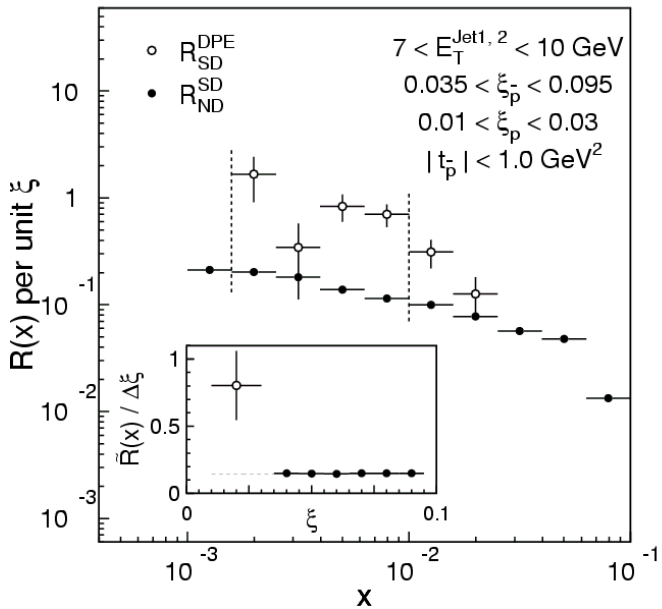
R(DPE/SD) ≈ k × R(SD/ND)

Question : k =1 ?

Answer :

R(DPE/SD) ≈ 5 × R(SD/ND)

⇨additional gap is un-suppressed



DPE Enhanced Sample

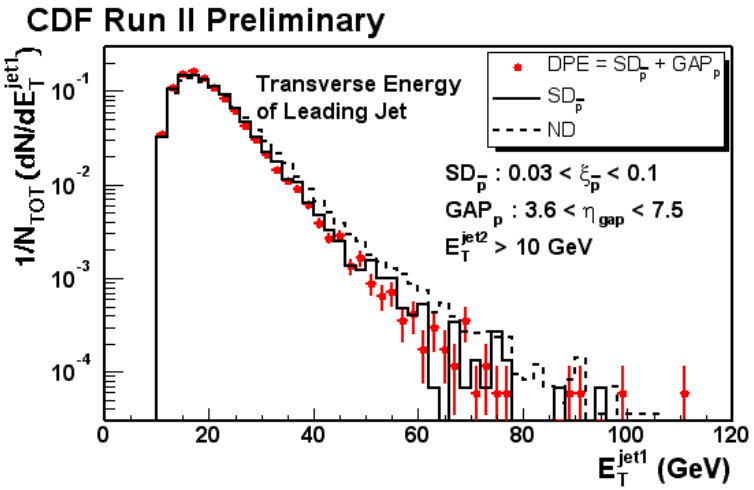
- **use dedicated DPE trigger (RP+J5+BSC_Gap_P)**

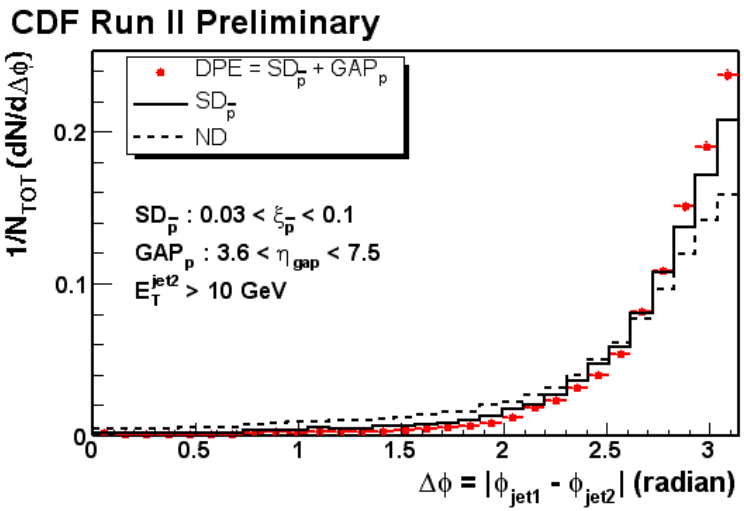
Data presented from 26 pb^{-1}:

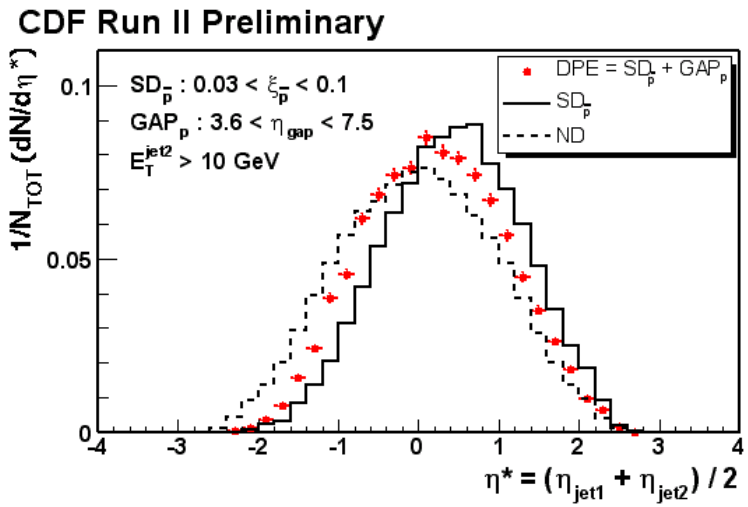
Triggers	397 k
$N_{vertex} \leq 1$, $\lvert z_{vertex}\rvert<60$ cm	365 k
RP offline cut	309 k
$N_{jets} \geq 2$ ($E_T>5$ GeV, $\lvert\eta\rvert<2.5$)	163 k
E_T(jet2)>10 GeV	116,473
SD ($0.01<\xi<0.1$)	54,552
DPE (MP-East $N_{hit}=0$)	17,101

DPE: kinematics

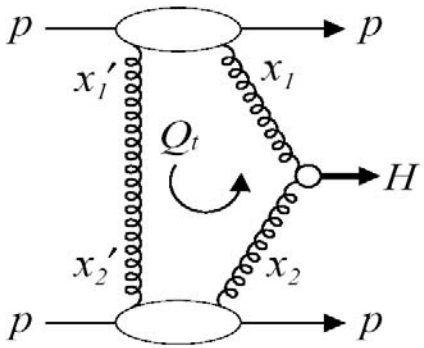
Compare ND and SD and DPE





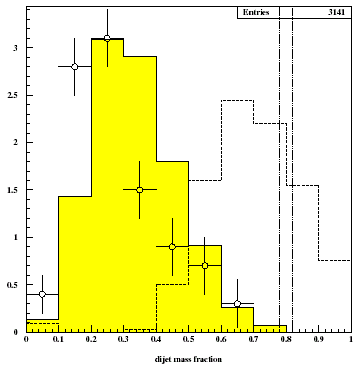


Exclusive Dijet Production

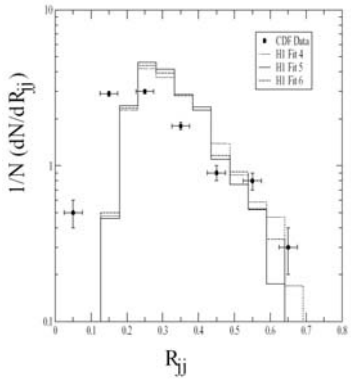


Higgs ?

Khoze, Martin, Ryskin
Eur. Phys. J. C23, 211 (2001), C26, 229 (2002)



Boonekamp, Peschanski, Royon
Phys. Rev. Lett. 87, 251806(2001)



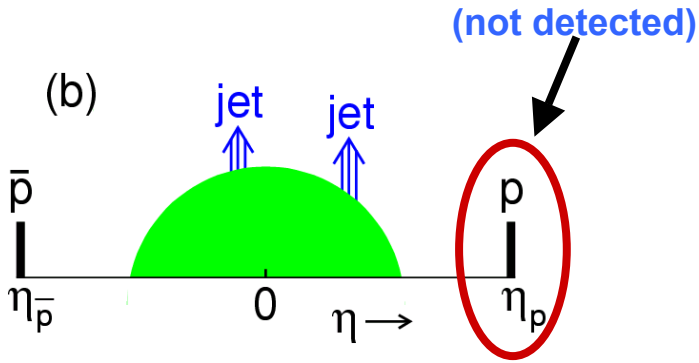
Appleby, Forshaw
Phys. Lett. B541, 108 (2002)

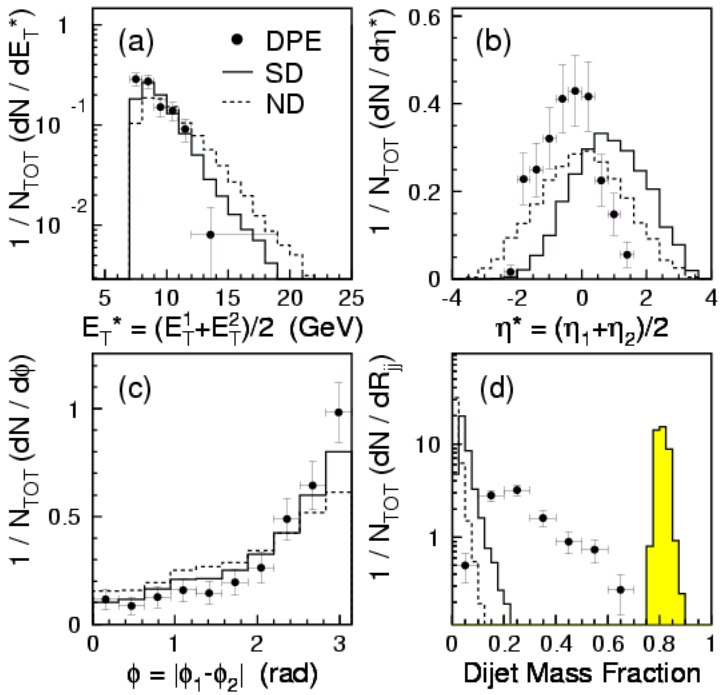
Exclusive dijets (using Run I kinematics): $\sigma \sim 1$ nb

Recent calculations: $\sigma \sim 60$ pb
($25 < E_T^{jet} < 35$ GeV, $|\eta_1 - \eta_2| < 2$)

?

Exclusive Dijets in Run I





✓antiproton tag: $0.035<\xi<0.095$

✓2 jets, $E_T>7$ GeV

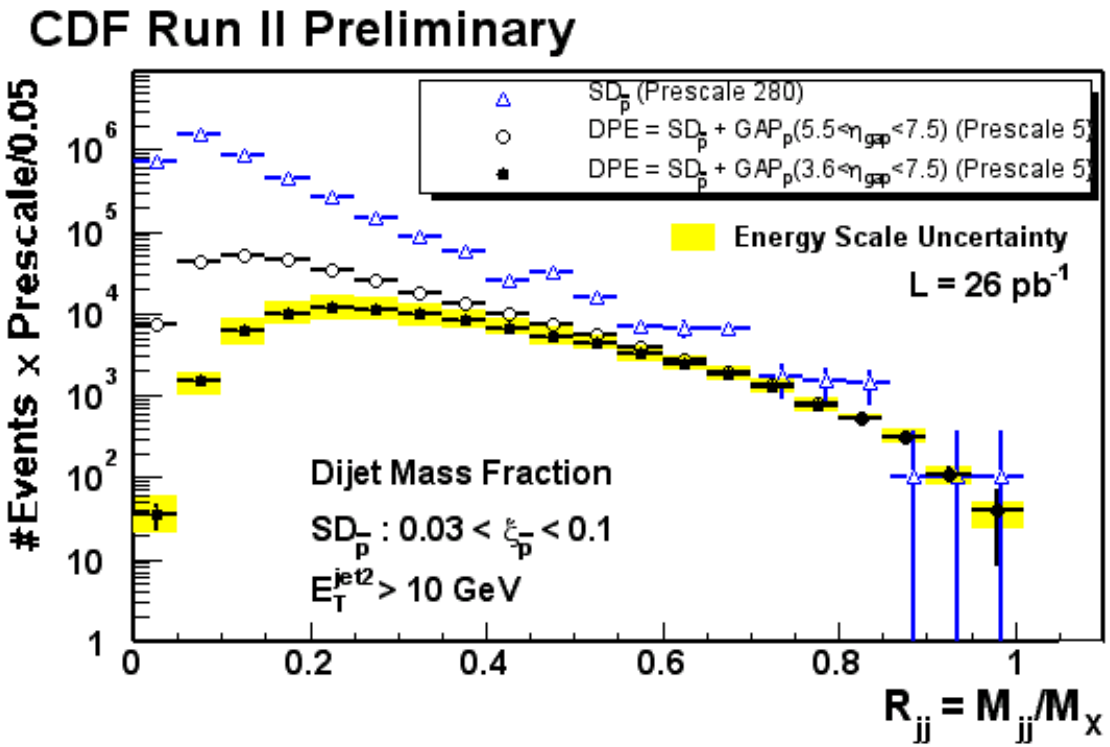
✓proton-side gap ($2.4<\eta<5.9$)

⇨ **observed 132 events**

Mass fraction: $R_{jj}=\frac{M_{jj}}{M_x}$

⇨ σ_{jj} (excl.) < 3.7 nb (95% CL)

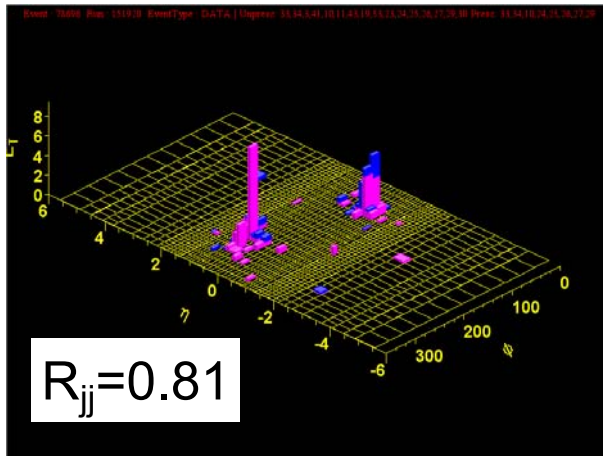
Dijet Mass Fraction

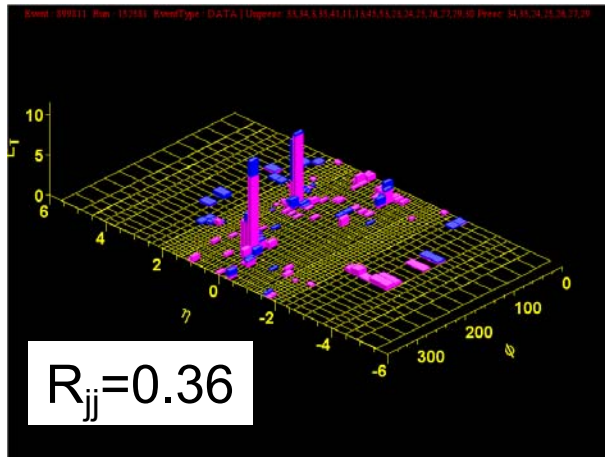


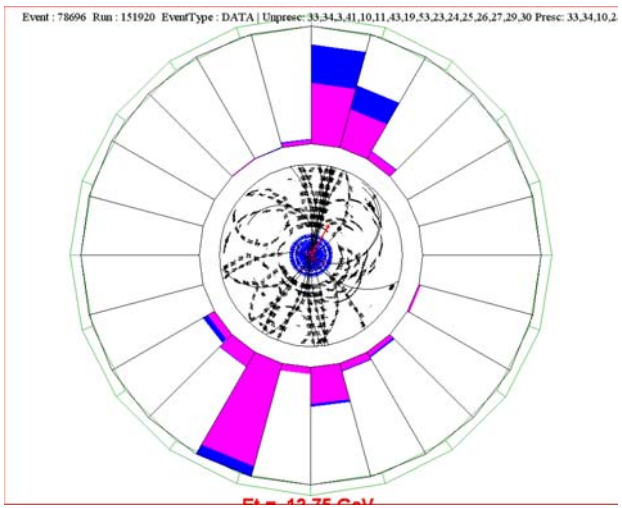
⇨ independent of rapidity gap size

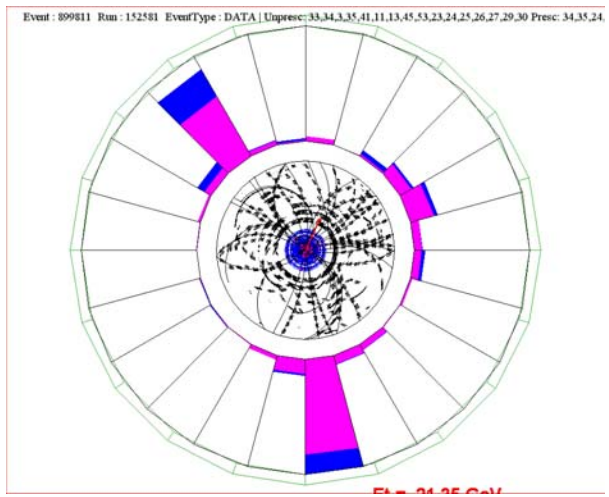
Minimum E_T(Jet1)	Cross section (R_{jj}>0.8)
10 GeV	970 ± 65(stat) ± 272(syst) pb
25 GeV	34 ± 5(stat) ± 10(syst) pb

Exclusive Dijet Events ?









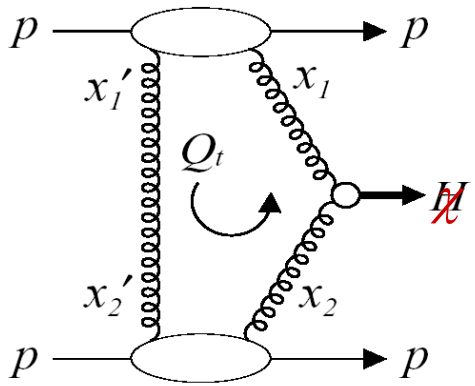
Exclusive low-mass states

$p\bar{p} \rightarrow p\chi\bar{p}$

$\hookrightarrow J/\psi\,\gamma \rightarrow \mu\mu\gamma$

(γ is soft)

(same quantum numbers as Higgs boson)



Event selection:

- ✓start from J/ψ sample
- ✓exclusive events
- ✓invariant mass (μμ+EM tower)

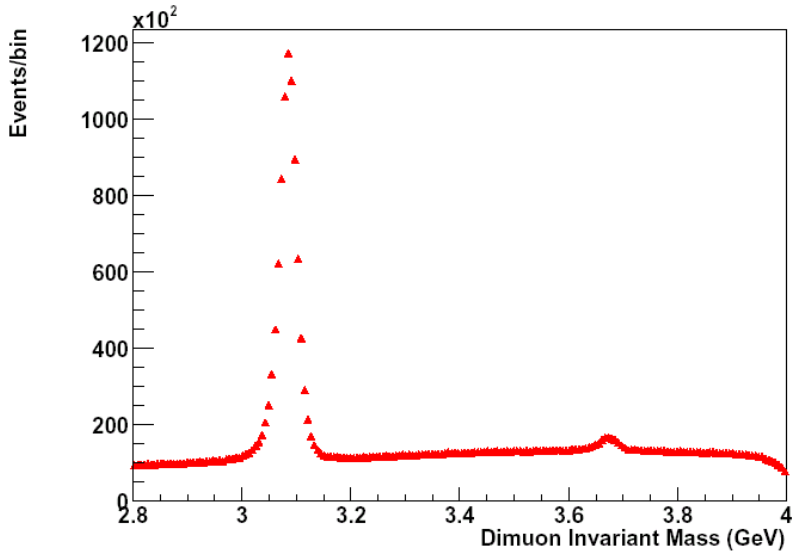
Background:

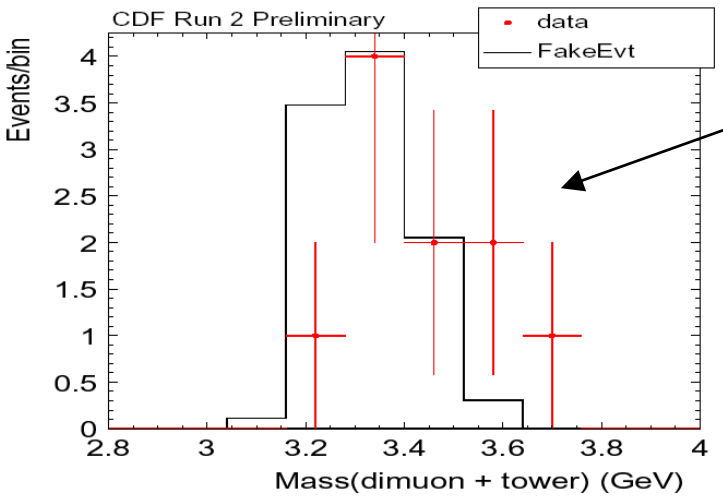
- ✓cosmics
- ✓calorimeter noise

Event Selection

Data sample of 93 pb^{-1} :

BSC+MP veto	107
(calorimeter+CLC+trk+muon) veto	23
EM tower	10





✓**mass resolution poor in both, worse in data**
✓**bckg from multiplicity fluctuations (under threshold)**
✓**difficult to estimate noise contribution**

cross section **upper limit** for exclusive production

⇨ $\sigma_{J/\psi+\gamma}$ **(excl.) = 49 ± 18(stat) ± 39(syst) pb**

Summary

- CDF forward detectors working well
- Dedicated diffractive triggers
- Re-established Run I measurements
- Preliminary results show no Q^2 dependence in SD/ND
- Increase in DPE events shows no exclusive dijet production

Run II analyses are well underway !

The ultimate Particle